Soil Temperature Signatures for Two Coastal Sand Dunes on Edisto Island, South Carolina

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Figure 1. Location of study area.


Figure 2. Partially vegetated sand dune at SC Site #5.


Figure 3. A PVC pipe protects the data loggers from the elements.


Figure 4. The soil was examined to gather a taxonomic classification.

Background

The National Soil Survey Center's Remote Soil Temperature Network (RSTN) was initiated in 1996 to acquire a soil temperature database for the entire United States. Hobo/StowAway temperature loggers were selected to capture air and soil temperature data from remote sites. The South Carolina Sea Island Global Change Project on Edisto Island was approved in 1996 to provide temperature data that will supplement currently approved Global Change Projects in the Caribbean area, Arkansas, Arizona, Hawaii, Idaho, Illinois, Iowa, Nebraska, New Hampshire, New York, North Carolina, Pennsylvania, Tennessee, Virginia, Washington, West Virginia, and Wyoming.

A total of 24 StowAway temperature data loggers with 1.8-m temperature sensor leads were installed at eight sites on Edisto Island, South Carolina, on November 18 and 19, 1996. Seven of these sites are wooded ecosystems. Site #5 was placed on a partially vegetated coastal sand dune adjacent to the Atlantic Ocean.

Purpose of Study

The primary purpose of this study is threefold:

1) To verify the thermic soil temperature regime on Edisto Island.

2) To identify the presence of a hypothesized isothermic soil temperature regime on coastal sand dunes adjacent to the Atlantic Ocean.

3) To identify if any of the sites attained soil temperatures below biological zero (5°C [41°F]) during the period of record.

Study Area

The study area is on Edisto Island, a sea island in southeastern South Carolina (Figure 1). Edisto Island's historical legacy began with the imprint of the Edisto Indians, its first known occupants. The Spanish arrived in the 1500s, followed by English settlers in the 1600s. The English remained; first living off the Ocean, then cultivated crops of rice and indigo. By 1790, planters turned to long staple cotton, known as Sea Island cotton, which is one of the finest cottons ever produced. It was cotton which brought great wealth to Edisto Islanders (www.digitel.net/edisto/history.html). Today, a few truck farming operations remain on Edisto Island but the biggest commercial industry is tourism.

The latitudes of the eight sites in the study area range from N 32°29'51" to N 32°34'59" and the longitudes range from W 80°13'58" to W 80°19'13". All of the sites are within 6 km of each other and their elevations are less than 7 m above sea level. Each site is fully vegetated except for Site #5 which is a partially vegetated coastal sand dune (Figure 2). Site #5, Site #6, Site #7, and Site #8 are either within 30 m of the Atlantic Ocean or a tidal marsh environment. The coastal sand dunes at Site #5 and Site #6 are less than 250 m apart. Differentiating site characteristics among the sites are presented in Table 1.

The soils at the sites are in the sandy particle size class except for Site #4 which is in a loamy particle size class. The soils classify as Quartzipsamments or Alorthods except for the Coosaw soil at Site #4 that is an Arenic Hapludult (Soil Survey Staff, 1996). Site #1 and Site #8 have a seasonal high water table above 100 cm while the other sites are either well drained or excessively drained.

References

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Methods and Materials

StowAway temperature loggers store 1,800 data points for periods ranging from 15 minutes to 360 days. Their certified temperature threshold is ±0.4°C (±0.7°F). Prior to installation in November 1996, they were programmed to collect temperature data every 4 hours and 48 minutes for 360 days. This frequency is the same as five times each day.

At each site, a 22-cm PVC pipe with a 10-cm diameter houses three StowAway temperature loggers and a desiccant pack to absorb excess moisture (Figure 3). Holes drilled in the PVC pipe allow 1.8-m sensor leads to exit outside while the temperature loggers are protected from the weather elements. These pipes were installed at eight sites in the study area on November 18 and 19, 1996. A hole was dug with a sharpshooter to a depth of 50 cm at each site. The soils were briefly examined to gather a taxonomic classification (Figure 4). One temperature sensor lead was tied to a tree sapling to capture air temperature and was generally placed from 60 to 90 cm above the soil surface. Two soil temperature sensor leads were installed at each site -- one at the 10-cm soil depth and one at the 50-cm soil depth. Finally, the PVC pipe was buried at about 10 cm and covered with soil.

After retrieval of the temperature loggers, the data were off-loaded on November 20, 1997, in Charleston, South Carolina. Once off-loaded, the temperature signatures were examined for each of the sites. Figure 5 graphically displays 3,600 soil temperature readings for the 10- and 50-cm depth at Site #5.

There are more than 41,000 readings (41,690) collected for this study. Site #2 through Site #7 yielded 100 percent data for all of the temperature loggers. Site #1 yielded 100 percent data for the 10-cm soil depth, 42.5 percent for the 50-cm soil depth, and 85.9 percent for the air temperature. Site #8 yielded 89.1 percent data for the 10-cm soil depth, 100 percent data for the 50-cm soil depth, and 100 percent data for the air temperature. The average percent capture for the 24 temperature sensors at the eight sites was 96.6 percent.

Average Readings From Eight Sites on Edisto Island

Averages of monthly temperature readings were calculated for air temperature, soil temperature at 10 cm, and soil temperature at 50 cm. Averages of the Mean Summer Soil Temperature (MSST) for June, July, and August, and the Mean Winter Soil Temperature (MWST) for December, January, and February were also derived. From those averages, the difference between MSST and MWST (MS-MW) were calculated. In addition, the minimum air and soil temperature readings were identified. The average, minimum, and maximum readings of each site are displayed in Table 2 while the average readings from the study area are shown in Table 3.

The average of the annual air temperature readings of the eight sites for the period of record was 18.66°C (65.58°F). This is within 0.25°C of the 30-year normal air temperature of nearby Charleston, South Carolina (18.44°C [65.20°F]). The highest average of the eight sites was 19.67°C at Site #5 while the lowest annual average was 18.08°C at Site #4. The lowest single low recorded reading was -6.8°C at Site #2 and the highest single low recorded reading for the period of record was -2.89°C at Site #6. The highest single high recorded reading was 43.89°C at Site #5 and the lowest single high reading was 31.34°C at Site #6. It is conjectured that heat reflecting from the non-vegetated soil surface accentuated the highest air temperature reading at Site #5.

The average of the annual soil temperature readings at 10 cm for the eight sites was 19.16°C (66.48°C). The highest annual average of the eight sites was 20.44°C at Site #5 while the lowest annual average was 18.03°C at Site #4. The lowest single low recorded reading was 9.37°C at Site #5 and the highest single low recorded reading for the period of record was 8.96°C at Site #4. The highest single high recorded reading was 35.72°C at Site #5 and the lowest single high reading was 25.76°C at Site #4.

The average of the annual soil temperature readings at 50 cm for the eight sites was 19.50°C (67.10°F). The highest annual average of the eight sites was 21.19°C at Site #5 while the lowest annual average was 18.72°C at Site #4. The lowest single low recorded reading was 10.12°C at Site #5 and the highest single low recorded reading for the period of record was 12.75°C at Site #4. The highest single high recorded reading was 29.19°C at Site #5 and the lowest single high reading was 23.59°C at Site #4. Monthly averages of the soil temperature at 50 cm for the period of record are presented in Figure 6.

The partially vegetated coastal sand dune at Site #5 had the highest average annual soil temperature at the 10- and 50-cm soil depths. Site #5 had the lowest single low value and the highest single high value for these depths. As conjectured, the average annual soil temperature at 50 cm is warmer than the average annual air temperature. This difference is 0.84°C (1.52°F) and compares favorably to the Tidewater Global Change Site in North Carolina that had a difference of 0.72°C during 1995 (Mount, et al., 1997).

The average summer soil temperature at 10 cm for the eight sites was 24.37°C (75.86°F). The highest average of the eight sites was 27.81°C at Site #5 while the lowest annual average was 23.12°C at Site #4. The average winter soil temperature for the eight sites was 12.93°C (55.27°F). The highest average of the eight sites was 13.83°C at Site #1 while the lowest annual average was 12.49°C at Site #5. Consequently, the average difference between mean summer and mean winter soil temperatures at 10 cm for the eight sites was 11.44°C (20.59°F). The highest average of the eight sites was 16.44°C at Site #5 while the lowest annual average was 9.75°C at Site #4.

The average summer soil temperature at 50 cm for the eight sites was 23.48°C (74.27°F). The highest average of the eight sites was 26.69°C at Site #5 while the lowest annual average was 21.92°C at Site #4. The average winter soil temperature for the eight sites was 14.41°C (57.93°F). The highest average of the eight sites was 14.92°C at Site #8 while the lowest annual average was 13.68°C at Site #6. The average winter soil temperature deviates only 1.24°C among the Edisto Island study sites (Table 2).

Consequently, the average difference between mean summer and mean winter soil temperatures (MS-MW) at 50 cm for the eight sites was 9.07°C. The highest average of the eight sites was 12.56°C at Site #5, while the lowest annual average was 7.03°C at Site #4. These analyses rule out the presence of an isothermic soil temperature regime on Edisto Island during the period of record.

Coastal Sand Dune Results

The partially vegetated coastal sand dune is clearly different from the vegetated coastal sand dune in its air and soil temperature signatures for the Edisto Island study (Figures 7 and 8). Contrasted to data at Site #6, the soil temperature signatures at Site #5 are unusual at both the 10-cm and the 50-cm soil depth. Figure 9 displays the monthly soil temperature at 10 cm for both coastal sand dune sites while Figure 10 displays the monthly soil temperatures at 50 cm (50 cm) for both coastal sand dune sites. The soil temperature at 10 cm cross over after February and before November at Site #5 and Site #6. Site #5 is warmer than Site #6 for most of the year at the 10-cm soil depth. The period from March to September is the time when this is most pronounced. The autocorrelation of the soil temperature at 10 cm and 50 cm resulted in an R^2 value 0.8145 (Figure 11). This indicates that there is a poor relationship among these two soil depths throughout the period of record. Is also suggests that if one collected measured soil temperature data at the 10-cm depth for an entire year, these data could not be adequately modeled to predict soil temperature for the 50-cm depth.

Other than February, Site #5 was warmer than Site #6 throughout the period of record (Table 4). Site #5 is more than 2.8°C warmer than Site #6 during May and from July through October. The fact that the average monthly temperature difference between Site #5 and Site #6 is 2.13°C (3.83°F) is significant. Exposed soil in partially vegetated ecosystems received more solar radiation and are warmer on a mean annual basis. This study suggests that land use practices such as clearing woodland for agricultural uses impact the mean annual soil temperature. Many studies have shown that cropland ecosystems are as much as 1°C warmer than adjacent forested ecosystems. A recent study in New York City revealed that a non-vegetated playground in Central Park is 3.1°C warmer than the adjacent forested ecosystem (Mount, et al., 1997. *Urban Soil Temperatures for Anthropogenic Soils in New York City*. USDA-NRCS. Presented at the ICOMANTH meetings in Las Vegas, Nevada, on September 22, 1998). The study on Edisto Island also supports that there is a major difference in the mean annual soil temperature based of earth cover.

Table 5 shows how the soil and air temperatures at Site #5 and Site #6 depart from the means of the eight sites. The biggest departure is the mean summer soil temperature (MSST) at Site #5 for the 10-cm and the 50-cm soil depths (3.44°C and 3.21°C respectively). While the averages for Site #6 are near the mean of the eight sites for nearly all the categories listed, the averages for Site #5 are either much higher or much lower than the mean of the eight sites. The minimum soil temperature value at 10 cm is nearly 7°C lower than the mean lowest temperature while the maximum soil temperature value at 10 cm is more than 7.5°C higher than the mean highest temperature.

The soil temperature threshold for discreet ranges at the 10-cm depth is presented in Figure 12 for the eight sites in the Edisto Island study area. Figure 12 graphically shows the impact of soil temperature frequency on the partially vegetated coastal sand dune at Site #5.

Discussion

All of the sites on Edisto Island are in the thermic soil temperature regime (Soil Survey Staff, 1996). The partially vegetated coastal sand dune at Site #5 is the closest to the hyperthermic soil temperature regime as presently defined in Soil Taxonomy. The hyperthermic soil temperature regime requires an average annual soil temperature at 50 cm of 22.0°C (71.6°F) and the average annual soil temperature of Site #5 is 21.2°C (70.15°F).

Based on vegetative cover, the two coastal sand dune soils within 30 m of the Atlantic Ocean on Edisto Island have a larger difference between average annual soil temperatures at 50 cm than originally hypothesized. In addition, the difference between mean summer and mean winter soil temperatures at 50 cm is greater than originally conjectured. The partially vegetated coastal sand dune soil has a difference between mean summer and mean winter soil temperature at 50 cm of 12.57°C while the vegetated coastal sand dune has a difference of 9.59°C. Soil Taxonomy requires that this difference be less than or equal to 6°C (10.8°F). The non-coastal soil at Site #4 came the closest to meeting the iso definition at 7.02°C. We offer no explanation for the temperature signature at 50 cm for Site #4 and attest that an additional year of data may provide needed information to understand its soil climate.

Consequently, this study rules out the possibility of iso temperature regimes along the Atlantic Seaboard, at least from Eastport, Maine, to Edisto Island, South Carolina. While it is possible an isothermic or an isohyperthermic soil temperature regime might exist near Savannah, Georgia, or to areas to the south, the question of where iso temperature regimes occur along the Atlantic Seaboard is presently an enigma.

Reduced biological activity at the 95 percent level (biological zero) occurs when the soil temperature is below 5°C (Paul and Clark, 1989). Biological zero was not identified on Edisto Island, South Carolina. The fact that the 10-cm depth at Site #5 was below biological zero for brief periods during December of 1996 and January of 1997 is of little consequence to the dominant soils and plant ecosystems of the island.

The average difference between the annual soil temperature at 10 cm and 50 cm is unusual. As Table 3 shows, the difference is 0.34°C with the 50-cm soil depth being warmer (19.50°C versus 19.16°F). StowAway temperature studies in West Virginia and Tennessee showed these differences to be within 0.1°C and a recent study on St. John Island showed these differences to be within 0.05°C (Mount, et al., 1995).

Monitoring soil temperature across the United States continues to be of primary interest to the Soils Division in the Natural Resources Conservation Service and the Global Change community. The Edisto Island Study is another segment of that commitment to measure and interpret the nature of soil temperature signatures.

Acknowledgments

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Table 1. Differentiating Characteristics for the Eight Temperature Sites on Edisto Island.

Site (No.)	Soil (Series)	Slope (%)	Aspect (°)	Vegetation (Dominant Kind)
1	Echaw	None	None	Cabbage palmetto, cherry, and honeysuckle.
2	Foxworth	None	None	Mature live oak glade with muscadine grape vines.
3	Foxworth	None	None	Loblolly pine and cedar.
4	Coosaw	None	None	Magnolia, sweetgum, and loblolly pine.
5	Newhan	7	300	Partially vegetated coastal dune w/ palmetto, yucca sweet grass, & seaoxeye.
6	Fripp	12	360	Vegetated coastal dune with live oak and palms.
7	Foxworth	25	270	Mature live oak, palmetto, and youpon holly.
8	Chipley	None	None	Mature live oak, loblolly seedlings, and honeysuckle.

Table 2. Temperature Summaries for Eight Sites on Edisto Island.

Site (#)	Sensor (Kind)	Average (°C)	Min (°C)	Max (°C)	MSST (°C)	MWST (°C)	MS-MW (°C)
1	10 cm	19.16	8.67	26.17	23.62	13.83	9.79
2	10 cm	18.76	8.47	26.24	23.54	13.12	10.42
2	50 cm	18.96	12.09	24.64	22.61	14.49	8.12
2	Air Temp	18.29	-6.84	34.81			
3	10 cm	18.64	8.48	25.84	23.34	13.27	10.07
3	50 cm	18.76	11.54	24.26	22.49	14.32	8.17
3	Air Temp	18.28	-5.16	33.74			
4	10 cm	18.58	8.96	25.76	23.12	13.38	9.74
4	50 cm	18.72	12.75	23.59	21.92	14.89	7.03
4	Air	18.08	-4.65	32.81			
5	10 cm	20.44	0.37	35.72	27.81	11.38	16.42
5	50 cm	21.19	10.12	29.19	26.69	14.13	12.56
5	Air Temp	19.67	-3.94	43.89			
6	10 cm	18.84	6.31	26.66	24.27	12.16	12.11
6	50 cm	19.01	10.67	25.03	23.27	13.68	9.59
6	Air Temp	18.73	-2.89	31.34			
7	10 cm	19.67	7.66	28.71	25.41	13.01	12.39
7	50 cm	19.93	11.26	26.27	24.46	14.44	9.59
7	Air Temp	19.01	-3.43	34.76			
8	10 cm	not enough data to determine annual average			23.83	13.23	10.59
8	50 cm	19.07	12.69	24.27	22.95	14.92	7.48
8	Air	18.54	-3.41	33.77			

Site (#) - site number on Edisto Island, South Carolina.
Sensor (Kind) - identifier for the subsequent temperature information. Average (°C) - average of 1,800 temperature readings.
Min (°C) - minimum recorded temperature for the period of record. Max (°C) - maximum recorded temperature for the period of record.
MSST (°C) - Mean Summer Soil Temperature based on average of readings taken during Jun, Jul, and Aug during the period of record.
MWST (°C) - Mean Winter Soil Temperature based on average of readings taken during Dec, Jan, and Feb during the period of record.
MS-MW (°C) - difference between MSST and MWST during the period of record.

Table 3. Averages of Air and Soil Temperatures at Eight Sites on Edisto Island, South Carolina.

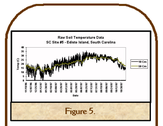
Sensor (Kind)	Annual (°C)	Min (°C)	Max (°C)	MSST (°C)	MWST (°C)	MS-MW (°C)
10 cm	19.16	6.99	27.87	24.37	12.93	11.44
50 cm	19.50	11.59	25.32	23.48	14.41	9.07
Air	18.66	-4.33	35.02	-----	-----	-----

Table 4. Monthly Soil Temperatures at 50 Cm for SC Site #5 and #6.

Month (Id)	Exposed Dune Site #5 (°C)	Vegetated Dune Site #6 (°C)	Site #5 Minus Site #6 (°C)	Month (Id)	Exposed Dune Site #5 (°C)	Vegetated Dune Site #6 (°C)	Site #5 Minus Site #6 (°C)
Jan	13.51	12.73	+0.78	Jul	27.88	24.22	+3.66
Feb	14.24	14.83	-0.59	Aug	27.19	24.05	+3.14
Mar	19.03	17.29	+1.74	Sep	26.83	23.40	+3.43
Apr	20.24	18.21	+2.03	Oct	23.81	19.49	+4.32
May	22.92	20.11	+2.81	Nov	18.00	16.17	+1.83
Jun	24.94	23.15	+1.79	Dec	14.65	14.00	+0.65
					Mean Difference		+2.13°C (3.83°F)

Table 5. Coastal Sand Dune Soil and Air Temperature Departures From Averages at Eight Sites.

Site (#)	Sensor (Kind)	Average (°C)	Min (°C)	Max (°C)	MSST (°C)	MWST (°C)	MS-MW (°C)
5	10 cm	+1.29	-6.63	+7.85	+3.44	-1.55	+4.98
5	50 cm	+1.70	-1.47	+3.88	+3.21	-0.28	+3.33
5	Air Temp	+1.02	+0.39	+8.88	-----	-----	-----
6	10 cm	-0.32	-0.68	-1.22	-0.10	-0.77	+0.67
6	50 cm	-0.49	-0.92	-0.29	-0.22	-0.73	+0.36
6	Air Temp	+0.07	+1.45	-3.69	-----	-----	-----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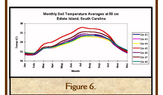
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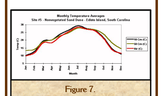
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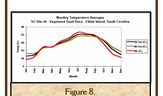
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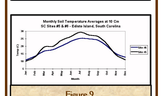
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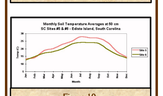
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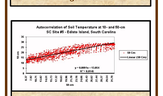
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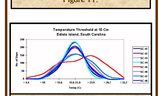
Figure 12.